

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 1/13/81

Project Title: ~~Collaborative Research:~~ Determination of Soil Properties with
the Self-Boring Pressuremeter

Project No: E-20-626

Project Director: Dr. Robert C. Bachus

Sponsor: National Science Foundation

Agreement Period: From January 1, 1981 Until June 30, 1982 (Grant Period)
September 30, 1982 (Rpt. Period)

Type Agreement: Grant No. CME-8012960, dated 12/16/80

Amount: \$27,282 NSF
2,565 GIT (E-20-357)
\$29,847 TOTAL

Reports Required: Annual Progress Report; Final Project Report

Sponsor Contact Person (s):

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Defense Priority Rating: N/A

Assigned to: Civil Engineering

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SPONSORED PROJECT TERMINATION SHEETDate July 12, 1983Project Title: ~~Collaborative Research:~~ Determination of Soil Properties with the
Self-Boring PressuremeterProject No: E-20-626Project Director: Dr. Robert C. BachusSponsor: National Science FoundationEffective Termination Date: 6/30/82 (1st year of continuing grant)Clearance of Accounting Charges: 2/9/83 (reference budget revision of 2/9/83)

Grant/Contract Closeout Actions Remaining:

NONE

- ☐ Final Invoice and Closing Documents
- ☐ Final Fiscal Report
- ☐ Final Report of Inventions
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NAME OF INSTITUTION (INCLUDE BRANCH/CAMPUS AND SCHOOL OR DIVISION)

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School of Civil Engineering

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Atlanta, Georgia 30332

PRINCIPAL INVESTIGATOR(S)

Robert C. Bachus - Geotechnical Engineering

TITLE OF PROJECT

Determination of Soil Properties with the Self-Boring Pressuremeter

TECHNICAL ABSTRACT (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

The actual stresses and strains induced in the soil by the insertion of a self-boring pressuremeter and inflation of its membrane will be studied. The effects of full or partial drainage on these measurements will also be investigated. This will involve theoretical, laboratory, model tests and field studies. This proposal is a 5 phase collaborative research effort between Stanford University and the Georgia Institute of Technology. Model tests, using an X-ray technique, on samples of uncemented and cemented sand and Kaolin clay will be performed by Georgia Tech in order to accurately define progressive strain patterns during a pressuremeter test. This data will serve as an important check on the ability of the analytical tools to model the actual soil behavior. The remaining 4 phases of the work will be conducted at Stanford University. The results of this collaborative proposal should provide improvements in pressuremeter data analysis techniques and thus, a better determination of soil behavior.

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COLLABORATIVE RESEARCH: DETERMINATION OF SOIL PROPERTIES
WITH THE SELF-BORING PRESSUREMETER

A 12-MONTH PROGRESS REPORT

for

The National Science Foundation
Geotechnical Engineering Branch
NSF Grant No. CME - 8012960

by

Robert C. Bachus
Instructor of Civil Engineering
Georgia Institute of Technology

INTRODUCTION

In January of 1981, NSF funded research for an advanced study of the self-boring pressuremeter. The grant was for a collaborative effort by Robert C. Bachus of the Georgia Institute of Technology and Professor G. Wayne Clough of Stanford University. The enclosed report summarizes progress of the research program at Georgia Tech during the past 12 months.

The self-boring pressuremeter is a state-of-the-art testing instrument for the in-situ determination of the behavior of soils. Although the device was originally intended for use in soft soils, recent technical modifications and improvements have facilitated its use in stiff clays and lightly cemented sands [1,3]. The majority of U.S.-based research on self-boring pressuremeter testing has been conducted by personnel from Stanford University under the direction of Professor G. W. Clough. While many of the difficulties involving the insertion of the probe and expansion of the membrane in various types of soils have been studied, a better understanding of the soil response to pressuremeter insertion and loading is needed. The current research effort addresses the study of the actual soil behavior through the following phases:

- 1) Design and construction of a scale model self-boring pressuremeter and support testing equipment for use within the laboratory, 2) Development of radiographic techniques for detailed monitoring of the deformation characteristics of the tested soil mass, 3) Utility of the new self-boring instrument in samples of Kaolin clay, sand and cemented sand, and 4) Evaluation of the conventionally used techniques for the reduction and interpretation of pressuremeter test results. Progress has been made in the first three phases of the project. Subsequent sections of this report

summarize the progress to date and indicate the anticipated work schedule for the forthcoming year.

DESIGN AND CONSTRUCTION OF LABORATORY SCALE MODEL SELF-BORING PRESSUREMETER

The prototype self-boring pressuremeter, originally developed at Cambridge University and later used extensively by personnel from Stanford, is a fairly rugged tool that can be carefully advanced into the ground to measure the in-situ stress-deformation characteristics of the soil mass. Measurement of the total lateral pressure, deformation and pore pressure at the boundary of the borehole wall are accurately monitored through the use of carefully calibrated strain gages [7]. The instrument developed for the present laboratory study was modeled after the Cambridge probe as far as general shape and instrumentation but was necessarily smaller in order to facilitate utility within the laboratory. The dimensions and capabilities of the prototype and the model instrument are compared in Table 1. Note that the instrumentation within each unit is essentially identical. Only one pore pressure cell is used in the model to facilitate construction. Although the model l/d ratio (the ratio of expanding membrane length to diameter) is slightly less than the prototype, it is much greater than the minimum required ratio of 2 found acceptable to guarantee membrane expansion as a right circular cylinder [7]. This design also considers the flexibility of utilizing thicker membranes (up to .050" (1.27 mm) if needed. Very thin latex bladders are desired in order to minimize the membrane inertia. Preliminary model tests conducted at Stanford indicate that a significant amount of data is generated at strain levels varying from .01 - .1% and thus a flexible membrane is required to prevent any "masking" of this data [1,2].

The model instrument has been constructed and calibrated. Owing to its small size, very detailed machining and sensitive instrumentation is required. As a final stage of probe construction, a strain gage power supply/readout unit is presently being developed to allow continuous display of each strain gage output as well as interface capabilities with an X-Y plotter, printer, or computer.

In addition to a model l/d ratio approaching that of the prototype, the length and diameter of the probe were determined by the physical limitations of the model test chamber. The constructed testing chamber is a 23" (58 cm) diameter steel cylinder, 12" (30.5 cm) high, mounted on a plexiglass base. The ratio of chamber diameter to probe diameter, 16.7, is believed large enough to eliminate the outer boundary effects intrinsic to the chamber. This system, however, maintains a great deal of flexibility in that the restraint of the outer boundary can be prescribed. By placing the material directly adjacent to the chamber, a condition of zero displacement at the outer boundary is maintained. By lining the chamber with a rubber membrane and using air pressure between the chamber and the bladder a pressure controlled boundary results. Displacement of this boundary can be monitored by use of dial gages or LVDT's during the course of pressuremeter testing.

The plexiglass base and the 12" (30.5 cm) chamber height are used based on constraints and limitations of the radiographic techniques developed for this program. The progress to date of this phase of the project is discussed in the following section.

Of major importance with any model testing program is the minimization of testing variables. For this reason special consideration is given to forming model specimens of consistent shear strength and uniform density.

For the sand testing program a 'sand rain' device, similar to one used by Jewell, et al. [4], was constructed and procedures are presently being developed to guarantee the formation of a uniform density model specimen. Techniques and equipment for the consolidation of large clay samples have recently been developed at Georgia Tech. Work is presently underway to determine mixing and testing techniques which result in rapid consolidation and uniform shear strength of the sample. Procedures for the formation of lightly cemented sand specimens have been developed by Sitar [6] and previously used by the principal investigator and thus will be followed for this program.

DEVELOPMENT OF RADIOGRAPHIC TECHNIQUES

One of the key goals of this research program is to develop techniques for detailed monitoring of the displacement of various points within the tested soil mass during pressuremeter testing. Work has been proceeding to develop radiographic techniques similar to those described by Roscoe, et al. [5] in order to achieve this goal. Essentially, this involves placing .12" (3 mm) diameter lead shot within the sample of soil and taking x-ray "photographs" of the sample at various stages of the pressuremeter test. The principle of operation is that a) the lead shot is small enough to not interfere with the soil mass and thus moves with the surrounding soil, and b) the x-rays can easily penetrate soil yet are blocked by lead. Therefore, a radiograph (the image produced on the x-ray film) will show the position of the lead shot within the soil mass.

Prior to the purchase of an x-ray machine for this project, preliminary testing was conducted using existing Picker x-ray equipment in the Nuclear Engineering Department at Georgia Tech. The results of these tests indicate that in order to penetrate 11" (27.9 cm) of either

sand or clay and still achieve suitable contrast of lead shot on the film, the following power requirements were required:

Voltage: 165 KV
Current: 25 ma
Time: 7 - 10 min.

The voltage and current are the maximum available from the unit. Therefore, in order to increase radiation dosage, the time interval is increased. Preliminary test results indicate that measured displacements as small as .001" (.025 mm) can be accurately monitored as long as the x-ray film is held in firm contact to the bottom of the sample and care is taken during development and processing of the exposed film. In spite of these successful procedures, a number of problems exist. These include:

- a) The 7 - 10 minute exposure time severely strains the existing machine and ultimately will reduce the life expectancy of any x-ray tube.
- b) The long exposure time is undesirable for measurement accuracy. During the actual pressuremeter test, radiographs are taken while the membrane is pressurized. The least bit of movement of the lead shot during exposure will represent a blur on the processed x-ray film, and thus reduce measurement accuracy.
- c) At the time the original proposal was prepared, a less powerful unit (lower KV and ma) than the Picker was considered. Based on these results, however, a substantially more powerful unit is required.

The solution to all these problems appears to be keyed to the recent acquisition of a used 150 KV, 1000 ma Phillips Medical X-Ray Unit. The unit was obtained from a transfer of excess government property from the V. A. Hospital in Durham, N.C. to Georgia Tech. The unit is currently in storage at the Geotechnical Laboratory at Tech, awaiting installation. The installation, and its effect to this project, is discussed in the subsequent Budget/Residual Funds section of this report; the unit is

certainly a valuable asset to this project. Of additional benefit to the present program is the extended capability of this unit, in particular the incorporation of a camera for use in time-motion studies. If use of this option is feasible for the present study a substantial amount of additional data regarding the interaction of pressuremeter and soil would be generated, possibly to include the visual determination of soil disturbance due to insertion. The potential use of this option is presently being explored by the manufacturers representative in the Atlanta area.

The radiographs obtained from the Picker machine are extremely promising. Film development techniques have been formulated for processing in the darkroom facilities in the Geotechnical Laboratory. Upon installation of the Phillips machine within the laboratory, modifications of the exposure procedures will undoubtedly be required. These, however, will be minor and well worth the effort due to the tremendous advantages offered by the Phillips unit.

MODEL PRESSUREMETER TESTING OF CLAY, SAND AND
LIGHTLY CEMENTED SAND
AND
EVALUATION OF CONVENTIONALLY USED ANALYTICAL
TECHNIQUES FOR REDUCTION OF PRESSUREMETER TEST RESULTS

The majority of effort expended thus far has been spent on the previously discussed two phases. Upon final calibration of the model pressuremeter concurrent testing of the clay and sand specimens will commence. It is anticipated that testing begin by November 1. Personnel involved in these latter phases have been studying the conventional analytical reduction schemes for interpretation of the pressuremeter test results, with particular emphasis placed on the assumptions of

deformations within the tested mass native to each technique.

SUMMARY - RESEARCH PROGRESS DURING THE FIRST TWELVE MONTHS

This research program involves the design and construction of both a laboratory scale model self-boring pressuremeter and support equipment for the model test program, the development of radiographic technique for monitoring deformations within the model specimen, and the testing and evaluation of the pressuremeter test results. The progress to date is summarized as follows:

- a) The model probe and support equipment is in the final stages of construction and instrumentation. The first tests on sand and Kaolin clay will be conducted by November 1.
- b) Radiographic techniques have been developed which result in accurately measuring movements as small as .001" (.025 mm) within the specimen. Acquisition of a used Phillips Medical X-Ray unit will undoubtedly result in higher quality radiographs, shorter exposure times, and possibly finer measurement detail.
- c) Sufficient background review of interpretation schemes has been completed such that reduction and evaluation of the pressuremeter test results can proceed immediately upon completion of the test.

Thus far four Georgia Tech Masters students have contributed to the present research effort. At Tech the Master's candidates are required to complete a "Special Research Problem" as partial requirement for the degree of MSCE. Captain Richard M. Gibbs (USAF) has completed the program by submitting a report entitled "Development of Laboratory Procedures for the Interpretation of Pressuremeter Test Results". Mr. Christopher E. Matza is in the final stages of his report entitled "The Development of a Self-Boring Pressuremeter for Use in the Laboratory". Mr. Gilbert M. Taylor and Ms. Carla Zambon-Ludwig are presently working on the testing and evaluation of results in sand and clay, respectively.

Table 1
Comparison of the Cambridge Self-Boring and the Laboratory
Scale Model Pressuremeters

Machine Dimensions	Cambridge Instrument	Model Pressuremeter
Overall Length	46.26" (1175 mm)	12.00" (304.80 mm)
Length of Expanding Membrane (ℓ)	20.28" (81.7 mm)	7.440" (199.98 mm)
Ex. Diameter (d)	3.22" (81.7 mm)	1.375" (34.93 mm)
Internal Diameter	2.00" (50.8 mm)	.400" (10.16 mm)
ℓ/d (expanding section)	6.30	5.41
Membrane Thickness	.050" (1.27 mm)	.010" - .050" (.25 - 1.27 mm)
Measurement Technique		
Total Stress	Gage pressure at surface Diaphragm strain gage in probe	Same as Prototype
Deformation	3 cantilever spring actuated "feelers" @ center of probe. Spaced @ 120° around circumference. Strain gages mounted on springs.	Same as Prototype
Pore Pressure	Diaphragm strain gage mounted within each of 2 pore pressure cells spaced 180° apart. Each cell is affixed to and moves with the center of the expanding membrane.	Same as Prototype except only 1 cell is used.

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